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SOME REMARKS ON SUSPENSION BRIDGES, AND ON THE COMPARATIVE MERITS OF CABLE AND CHAIN BRIDGES.—*By J. A. Roebling, Civil Engineer. No. 2.*

Storms are unquestionably the greatest enemies of suspension bridges. As to the action of the wind, however, upon these structures, there appears to be a diversity of opinion among Engineers. I will offer some remarks which are the result of observation and reflection.

Those who have had an opportunity of examining chain bridges, will know that it requires comparatively but a small force to put the chains and the whole floor in an oscillating motion, as they are suspended vertically, and will follow the laws of the pendulum.

Railings and longitudinal vertical trusses will not prevent these oscillating motions, but a stiff and well-constructed floor will offer a great resistance.

The floors of almost all the English suspension bridges are entirely too light; better specimens in this respect are to be found on the Continent.

When the force which sets a pendulum in motion is continued to be applied at regular intervals, which correspond with the oscillations and their directions, the effect will be a great extension of these oscillations. The scope of oscillations of the heaviest weights thus suspended and operated upon, may be very much increased. Forest trees which have withstood the effects of storms for ages, have only escaped the fate of other less fortunate individuals, because the gusts of wind never happened to correspond with the oscillating motions of their tops. Chance saved them. It is the

same case with suspension bridges. When a high wind blow sideways against the floor and railings of a suspension bridge, an oscillating motion to a small extent will soon be produced. The irregular succession of gusts of wind, which but seldom will correspond with the oscillations of the bridge, will be the very means of stopping them; and thus many a bridge has withstood the fury of gales unhurt.

But suppose, while the bridge is oscillating to a great extent, another furious stream of air happens to strike it, just at the time it is moving in the same direction, the effect which then will be produced cannot fail to be destructive.

Thus, we see that a mere calculation of the effect of wind upon a body when suspended, will give a result far short of what actually may and has taken place.

Vertical currents of air may be, no doubt, as violent as horizontal currents; but the former will never do much harm to a well-constructed bridge.

The experience in suspension bridges was very limited at the time Mr. Telford displayed the power of his genius by the erection of the noble Menai. No provisions were made by him to secure the platform against the action of vertical currents, although the position of that bridge admits of the most effectual application of remedies which will never fail.

Mr. Brunel, jr., was the first who applied the proper means to guard against the effect of vertical currents, and to a certain extent also against side currents, in the construction of a suspension bridge on the Isle of Bourbon, where hurricanes are of frequent occurrence.—(*See Navier's Memoir sur les Ponts Suspendres.*) In this bridge the platform is held down by stages, fastened by the lower ends to reversely-curved chains, the ends of which are secured in the piers and abutments. Thus the platform is completely secured vertically. At the same time the ends of these reversed chains recede from the bridge horizontally, and act as diagonal stays in the latter direction.

The same expedient can be applied to the Menai bridge more effectually, as the floor is elevated nearly 100 feet above the water. This, together with strong cast iron parapets, and a better constructed floor, would no doubt insure the safety of this noble work for all ages to come.

Chains are suspended in vertical planes, and when put into a swinging motion, cease to offer a uniform support to the suspension rods.

Cables are, and should always be suspended in inclined, or rather

curved inclined planes; but this cannot be done with chains. Herein consists one of the main superiorities of cables over chains.

The planes, in which the cables are suspended, being inclined towards each other, give at once to the floor a horizontal stability, especially at the middle of the bridge, where it is most needed. It requires a wind of great force even to displace a platform thus suspended, to any extent, and regular oscillations are next to impossible.

This principle of inclining the cables may, in situations exposed to frequent storms, be carried out to a greater extent than it has been. It is necessary, however, in such cases, that the cables should be supported by towers, and not single unconnected columns, as they have a tendency to thrust the latter towards each other.

The Friburg bridge is suspended by four cables of 5¼ inches each in diameter. Two cables are placed on each side. There is, however, no practical difficulty in uniting any number of cables into one single cable, so that there may be but *one* cable on each side, to which all the suspenders on that side are attached. A single cable will be superior to a pair of cables when displaced by lateral forces. The arrangement of the cables in inclined planes is also rendered easier, when but one cable is formed, than when they are collected into pairs.

In order to increase the vertical stability of suspension bridges of a great span, it will be useful to bring the weight of the cables into action by connecting them with the floor at intervals, either by timbers or cast iron pipes, which may include the suspenders. The floor then cannot be raised at any place without lifting a considerable portion of the cables and of the whole bridge.

The greatest trial to which a suspension bridge may be subjected, next to storms, is the march of a body of soldiers, moving over it in regular file and step. A crowd of people, moving promiscuously, will not produce a strain so severe as the momentum of a much smaller body of men, the united weight of which is rising and falling at regular intervals. In the latter case, a regular vertical oscillation of the platform longitudinally will take place, and the momentum of the load will unite with the momentum of a great portion of the bridge, in producing shocks which greatly exceed the strain produced by a promiscuously moving load. Heavy railways and stiff connections between the floor and cables, and a stiff floor, will contribute much to counteract such effects.

Large bodies of troops, when moving over such bridges, should always be ordered out of step. Several accidents produced by the above cause are now on record.

The above remarks have not been made with a view of bringing suspension bridges into discredit. To impute such a motive to me would be unjust. No one can be a greater admirer of the system than myself. The superiority of these structures, and especially cable bridges, over all other kind of bridges, needs no argument of mine. Abler men have established this long ago.

In speaking of the weak points of the system, I have only intended to show how much caution is necessary in planning and executing a suspension bridge in order to insure perfect safety. It appears that the destruction of so many wooden bridges by the late freshets, would urge the adoption of a system which is beyond the reach of ice and floods. But, to insure the successful introduction of cable bridges into the United States, their erection, and especially the construction of the first specimen, should not be left to mere mechanics. No modern improvement has profited more by the aid of science than the system of suspension bridges. And we see that all the noble and bold structures of this kind which have been put up in Europe, were planned and executed under the immediate superintendence of the most eminent Engineers, whose practical judgment was aided by a rich store of scientific knowledge.

For the American Railroad Journal, and Mechanics' Magazine.

"DEPOTS AND GROUND FOR RAILWAYS."

MESSRS. EDITORS:—You were good enough to call my attention to a correspondent at Chatham Centre, with the remark that he was an Engineer, but you were not at liberty to give his name.

It is to be regretted that your correspondent has not used his pen to advance the cause of Railways, instead of making an unimportant and incorrect criticism on the article in your paper of the 1st October, 1840, with the above caption.

I trust a plain statement of the cost of land, depots, damages, &c., for the Western Railroad, on which I have reason to believe he has been engaged, will put him to the blush, if he will read the last report, as well as the previous ones, on this important thoroughfare. I shall quote from the last report, to prove that I am correct in all the essentials of the article referred to. It is introduced as follows:—

"Few Railroad Companies, at the commencement of their works, are aware of the extent of ground required for the accommodation and cover of their engines, for their cars, workshops, wood and station houses, &c. The consequence is, in the outset the Directors secure but partial accommodations, and afterwards

have to pay extravagant prices, when their power by the charter to take land for the purposes of the road, by appraisement, is exhausted by non-user. They are then at the tender mercies of individuals, who are generally as heartless as the corporation they have to deal with; and any advantage that can be taken of a 'soulless company' is considered fair, *although the construction of the road is the main value given to their property.*

"We are led to make these remarks from reading the reports of the Camden and Amboy Railroad Company, where the items of real estate, land, damages, for *the right of way and necessary ground*, is stated at $371,769, or $4,041 per mile."

The cost on several other roads is then noticed for "*depots and ground for ways*," varying from $2,000 to $7,000, with the remark, (which appears to have excited the ire and criticism of your correspondent): "The Western Railroad Company of Massachusetts, over the mountains and rocks of Berkshire, have paid at the average rate of $1,700 per mile, or above $200 per acre, taking the general width of railways, 4 rods, or about 8 acres." We ask, what average of $1,700 per mile?—of course the whole road. What general average width of railroads? Four rods.

Your correspondent makes some long shots, wide of the mark, when he states, "The Western Railroad is nearly as often 15 rods wide as 5 rods in Berkshire county—varying from ten to thirty acres to the mile."

This, however, let me remark, has nothing to do with the question; nor his subsequent remark, "I think, Messrs. Editors, that the actual cost of the land (land only) may be set down considerably nearer $2 per acre than $200."

Let us look into the truth of this assertion, from facts drawn from the "*Annual Reports of the Railroad Corporations in the State of Massachusetts for* 1840."

At page 54, treating of the cost, in detail, of the Western Railroad, for 54½ miles east of the Connecticut river, we find that "depot lands, for eleven stations, 20 acres, cost $5,543," (or $277 per acre.) Again, "land, damages, and fencing, including lands for changes of highways, expenses of reference, cost $89,023," or equal to $1,730 per mile, or above $200 per mile. To these items we have to add, for "depot buildings, including repair, shop and machinery at Springfield, aqueduct, furniture for station houses, and fixtures, $73,500," or $3,080 per mile.

Let me refer now to "the estimates of the cost of the Western Railroad *west* of the Connecticut river, for 62½ miles. What do we find at page 61? "Depot lands, at ten stations, $5,041, with

land damages [right of way] and fencing, $89,458," or $2,220 per mile, instead of $1,700.

The Massachusetts report remarks, page 66 [which supports the doctrine advanced Oct., 1840], "In 1838 it was supposed that lands for depots would be given west, as it had been, in most cases, east, of the river; but the company were compelled to pay for this object"—!!!—?

Again, on the same page: "The present depot arrangements at Boston are found to be wholly inadequate * * "— "The increasing business at Springfield would also require considerable additions to the accommodations of that station beyond those already estimated for and provided."

In treating of the cost and estimate for the continuation of the Western Railroad from the New York State line to Albany, with reference to land damages and depots, the report says, pages 70 and 72:

"On reviewing the estimates of the former Engineer, nothing is found included for the cost of purchasing and grading a depot at Greenbush, &c. Tne estimate for the *roadway* proved to be very inadequate."

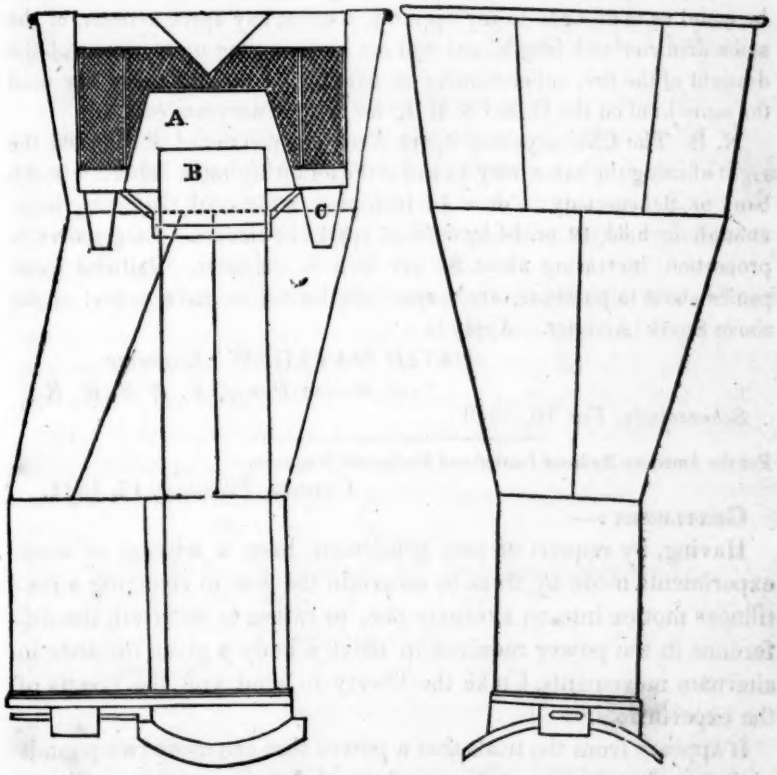
The estimates (page 72) for "land, depots, and fences," for 38 miles, is stated to be $190,070, or $4,990 per mile; this does not include "the depot in Albany and steam ferry-boat, $65,000." Little is ventured in stating, that these estimates are much within expected payments, simply from the Albany and West Stockbridge Railroad not getting the right of way before they sold out to the Western Railroad, who put the road under contract, with hot haste, to occupy the ground, ere they had secured the titles on which to construct it. The article criticised was written to inculcate the doctrine, that it was necessary, as a step of the first consequence, in building railwrys, to get "*the right of way* and ground for depots," ere a company placed themselves "at the tender mercies of individuals." I also had the desire to add my mite, in aid of the valuable essay of William R. Casey, C. E., first published in your Journal of 1st Oct., 1839, on this subject.

In my remarks on "the Rocky Mountains of Berkshire," no disparagement was intended to that rich manufacturing county, by the introduction of its valuable rocks of granite and marble. That some of her rocks are sufficiently hard to make a road through of only two rods in width, we think some of the contractors will testify to. What your correspondent, or the Western Railroad, will do with 15 rods of land in width *for the roadbed*, in that or other regions, except to get dirt for embankments, we leave him to inform

us. Certainly not 15 rods, nor are 5 rods necessary for the railway tracks, although 4 rods is generally taken; yet few roads occupy 3 rods. Where there are flats and high embankments required, it may be cheaper to buy 15 rods in width, to get earth, for short distances; but for the tracks of a railway, it is preposterous.

J. E. B.

There appears to be no greater desideratum in railroad machinery than an efficient spark arrester. The description of the invention of Mr. Daniel Matthew appears to satisfy this most important want; and, judging from the favorable notices in various quarters, and also from the experiments which are described, we cannot but consider that he has rendered valuable services to the travelling communities, as well as to railroad companies.



THE following statement is from a course of experiments made on the Utica and Schenectady Railroad with a new SPARK ARRESTER and CHIMNEY, recently patented by *David Matthew*, Engineer of motive power on said road, viz:

Two locomotive engines started with ten cars each behind the engine and tender, on the 4th and 5th days of February inst., with an open box

two feet square, placed on the third car, or between 25 and 30 feet behind the tender, the bottom of which was covered with fine dry gun powder, and fluted in such manner as to prevent the possibility of the powder gathering in one place, the crevices in the bottom being all the time kept full.

1st. Trial. Engine No. 2, run 30 miles before the powder took fire.

Engine No. 4, run 148 miles before the powder took fire.

2d. Trial. Engine No. 2, run 48 miles before the powder took fire.

Engine No. 4, run 115 miles before the powder took fire.

3d. Trial. Engine No. 2, run up and down the whole line of the road, being 156 miles, and did not set the powder on fire. The experiment was stopped in consequence of snow. The foregoing experiments were made with the powder all the time in the same exposed situation; weather clear and mild; the engines using hard and soft wood, and running at the rate of 20 miles per hour.

The above mentioned Chimneys and Spark Arresters are warranted to be equal as to draught to any open top, without any spark arrester, of the same diameter and length, and will not gum or clog up so as to stop the draught of the fire, either running or standing, as the subscriber has used the same kind on the U. and S. R. R. for nearly two years past.

N. B. The Chimneys and Spark Arresters mentioned above, and the right of using the same, may be had at the following rates, delivered in Albany or Schenectady: For a 14 inch pipe, $150, with the casing large enough to hold 12 or 14 bushels of sparks or cinders. Larger sizes in proportion, increasing about $5 per inch in diameter. Railroad Companies about to purchase, are respectfully invited to make a trial of the above Spark Arrester. Apply to

DAVID MATTHEW, *Engineer*
of Motive Power, U. & S. R. R.

Schenectady, Feb. 10, 1840.

For the American Railroad Journal and Mechanics' Magazine.

COHOES, *February* 17, 1841.

GENTLEMEN:—

Having, by request of two gentlemen, been a witness of some experiments made by them to ascertain the loss in changing a rectilinear motion into an alternate one, or rather to ascertain the difference in the power required to move a body a given distance in alternate movements, I take the liberty to send you the results of the experiments.

It appears from the trials that a power that can move two pounds each four feet per second, one of which has a constant rectilinear motion and the other a reciprocal motion, can only move the two pounds in one mass in the latter motion 2 $\frac{66}{100}$ feet per second, and the single pound alone, moved in the same manner, only 5 ^{10} feet per second.

It is believed the difference would exceed the above results were the apparatus more perfect.

It is proper that I should inform you why they were induced to make these experiments. They are the inventors of a rotary steam engine, in which the force of the steam acts constantly in a direct manner upon two rotary pistons; they believe their engine has an advantage over the reciprocating engine in consequence of the alternate movement of the piston of the latter; hence the experiments.

The gentlemen are William H. Baker and Samuel H. Baldwin. They are to renew the experiments as soon as convenient, with a more perfect machine, when I will send you a description of the method of experimenting.

Respectfully,

CHARLES A. OLMSTED.

We are exceedingly sorry that so large a list of errors should be selected as the following from the late communication of Mr. Cushman—but in the first place, the "copy" was of the most intricate kind, full of complicated formulæ; and in the next place, Mr. C. is not particularly careful in distinguishing signs or letters resembling each other.

The proof was sent to Mr. C., and the Journal was delayed some time in order that we might hear from him, and we were at last obliged to go to press without receiving Mr. C.'s proof—but not until it had been carefully read three or four times in the office.

The communication we received from Mr. Cushman, together with the errata, is such as we cannot publish, and would not notice, were it not necessary to publish the errata themselves.

ERRATA.

Page	2nd,	26th line,	"*expressed*" has been misprinted for	expended.
	7th	32nd "	"(co z A—)" "	(co z—A)
	"	33d "	"*revolution* of P" "	resolution of P
	34th	27th "	"$\sqrt{1-\text{sine A}}$" "	$\sqrt{1-\text{sine}^2 A}$
	"	29th "	"integration by *sines*" "	intergration by series
	35th	5th "	"each *fraction*" "	each function
	"	6th "	"*engines* which affect,&c." "	signs which affect,&c.
	"	11th "	"$+\cos z \cos z \frac{l}{2r}$" "	$+\sin z \cos z \frac{l}{2r}$
	"	15th "	"$-\sin^2 z^2 \frac{l}{4r}$" "	$-\sin^2 z \frac{l}{4r}$
	36th	6th "	"2^2" "	z^2
	"	24th "	"proportions" "	proportion

Page 37th, 8th line	"$\frac{2r}{2}$=ton z"		$\frac{2r}{l}$= ton z
" 28th "	"points"	"	pivots
38th 3d "	"$(\frac{1}{2} l. \overline{1 \cos z})$"		$(\frac{1}{2} l. \overline{1-\cos z})$
" 10th "	"*cos*, as the value," &c.	"	or, as the value, &c.
" 17, 19 & 21	"points"	"	pivots
" 24th line	"2 and r"	"	m and r
" 26th "	"to and *from*"	"	to and fro
40th 8th "	"points"		pivots

Our readers may remember that some time since we commenced copying a series of articles on the Steam Engine from the Am. Repertory. As they referred to articles inserted or copied into our Journal, we thought it best to give them entire, and when concluded to answer them. We soon found, however, that we were encumbering our pages to no purpose, and that no person of any pretensions to science would deem an answer necessary.

Several of the wholesale assertions of this writer have been taken up by various writers in the Am. Repertory. The annexed communication, which we take the liberty of copying from that Journal, is in answer to one of them.

We would beg leave to ask, however, whether this writer who labours so earnestly to deprecate the labors of our mechanics, is not himself a foreigner, with strong prejudices, and therefore not the most suitable judge among our own artisans?

GREAT WESTERN AND NORTH AMERICA.

The indefatigable writer "On the Steam Engine," whose peculiar ideas on the properties of steam occupy such a prominent and ample space in the pages of the American Repertory, having in the last number so far departed from truth as absolutely to assert that in the engines of one of the best steamboats on the Hudson River, "*only half as much effect is obtained from a ton of fuel as in those constructed on the other side of the Atlantic*," I feel called upon to trouble its readers with a few remarks, to expose the absurdity of a statement evidently advanced for the purpose of inducing a belief that the gratuitous supposition of an existing ignorance of the advantages of expansive steam is really borne out by fact.

The foundations on which the bold assertion is made, that a given quantity of fuel is twice as effective in the Great Western as in the North America, are as follows:—"The Great Western consumes 28 tons of bituminous coals per 24 hours; the North America, 10 tons anthracite coals in 10 hours," (or 24 tons per 24 hours.) "The heating power of the fuel in each vessel" is next shown "to be very nearly the same; and it is further added, that "a trifling difference is of little value in our argument."—(See Repertory for January.)

The average speed of the two vessels on which the calculations are made, is, for the Great Western 8·5 miles, and for the North America 14·5 miles per hour; and the respective resistances, according to well known laws, are correctly stated to be in the ratio of 70·25 to 210·25, for equal sections, displacement, &c.; and further, the average displacement of the Great Western is estimated at five times that of the North America. On these grounds our acute writer exclaims: "Can we then doubt that the fuel is fully twice as efficient in the Great Western as in the North America?"

The assumed fact, that in consequence of the Great Western having five times greater *displacement* than the North America, the resistance of the former, at any given speed, will also be five times greater, I will suppose to be correct, in order to avoid a very lengthy demonstration, only observing that the average immersed midship section of the Great Western is four times that of the North America, and her superficial measurement less than $2\frac{1}{2}$ times that of the latter.

The heating "power" (effect) of the fuel consumed in both vessels (28 tons bituminous coals in the Great Western, and 24 tons of anthracise in the North America) being stated to be alike, it follows that the effect produced in the former vessel ought to be twice as great as in the latter; or, in other words, that her engines ought to be twice as powerful in order to justify the assertion that "a ton of fuel in the Great Western is twice as effective as in the North America." A very short demonstration will convince the reader of the utter fallacy of this assertion.

The resistance opposed to the progress of the North America being to that of the Great Western, for equal displacement, section, &c. as 210 to 70, owing to the difference in speed; and their respective displacements being as 1 to 5, it follows that the *relative* resistance of the Great Western will be $5 \times 70 = 350$, and that of the North America 210. But the latter vessel will pass over a space of 14·5 miles, whilst the former passes over 8·5 miles. Hence, the relative force necessary to be exerted *during equal periods*, will be, for the Great Western $8{\cdot}5 \times 350 = 2975$, and for the North America $14{\cdot}5 \times 210 = 3045$. Thus proving that the power of the North America's engines absolutely exceeds that of the Great Western, and also that the consumption of 24 tons of anthracite coals in the former actually produces a greater effect than 28 tons of bituminous coals in the latter! With such a result, deduced entirely from his own premises, our profound writer "On the Steam Engine" assures the readers of the American Repertory that the North America, which he styles "one of the proudest achievements of American engineers," is so defective that only one half the effect is produced by a given quantity of fuel, as compared to the Great Western!

I forbear to animadvert on the loose reasoning which has led to such erroneous conclusions on a subject of grave importance; though I cannot refrain from observing, that the pompous style forms a striking contrast to the unsoundness of the views expressed; and I may be permitted to express an opinion, that the readers of

the American Repertory would be benefited in a much higher degree by the many important practical facts communicated by the industrious writer "On the Steam Engine," if they were altogether unaccompanied by his comments. J. E.

New-York, 20th January, 1841.

A PROSPECTIVE VIEW OF PENNSYLVANIA IN RELATION TO HER SYSTEM OF INTERNAL IMPROVEMENTS, WITH SPECIAL REGARD TO THE PROPOSED PHILADELPHIA AND PITTSBURG RAILROAD.—NO. 1.

In these days of commercial gloom and prostration of business, it behoves us to look calmly at the resources which are at our command to repair our sunken fortunes, and on which we can mainly rely for the stable basis of our future national welfare.

As an agricultural district, Pennsylvania certainly ranks high, but can, in the nature of things, never become as important as some of the Western States will in the course of time. We have good soil enough to support a large population, but we never will have much to spare after supplying our home market.

As a commercial State, we cannot boast, to speak the truth, of occupying a very enviable position; some of our sister States have great advantages over us in that respect, and it is vain to deny it.

What great source of wealth is then left to Pennsylvania above other sections of the Union? We answer, *her immense mineral wealth, and consequent facilities for manufacturing.*

The mineral resources of Pennsylvania cannot be easily over estimated, when we look at the immense wealth which Great Britain has amassed by properly developing her resources, and thus making the wants of other nations subservient to her interests. The position in which England now stands to almost the whole of the globe, Pennsylvania is destined to assume, at least relative to the Continent of America.

To show what an important bearing a judicious improvement system has upon the success of mining and manufacturing operations, we need only point to Great Britain. The unparalleled progress of that country is to a very great extent owing to its facilities of intercommunication. Good turnpike roads, canals and railroads, are looked upon as the artificial arteries of a country through which the products of industry are flowing in all directions.

Distances have been and can still more be reduced by the application of steam. The improvements in railroad and locomotive engines will, it appears, contribute as much to the advancement of our country as all the other improvements of a modern origin together.

Let us complete our Erie Extension and North Branch Canals, which, when finished, will both contribute largely to the successful development of our resources, and will enable our improvements to pay for themselves.

The particular attention of our readers, however, is here called on to take into due consideration the vast importance of establishing a continuous line of railroad from our eastern metropolis to the Birmingham of the west.

The Columbia, Harrisburg, and Lancaster Railroad, form a continuous line to Harrisburg, a distance of 106 miles; 242 miles remain to be constructed from Harrisburg to Pittsburg to make the connection complete between the Delaware and the head of the Ohio river, at a total distance of 348 miles; and this can be accomplished at a moderate expense, not exceeding the average cost of good railroads in the Eastern States, and

without a single inclined plane, and no grades exceeding 45 feet per mile.

We feel it our duty to dwell upon this important matter at some length, and to endeavor to make the citizens of Pennsylvania, and especially those of Philadelphia and Pittsburg, aware of the highly interesting fact, now established by actual survey, *that within our own borders, and nearly through the centre of the State, a route for a continuous railroad exists which can boldly challenge all the other States in the Union, without a single exception, and which can successfully compete with all rival routes which have already been established, or may yet be between the tide of the Atlantic Ocean and the Mississippi Valley!*

By the citizens of Philadelphia this important news ought to be hailed with joy, as by this fact, if the advantage is taken in time, the current of trade may once more be turned in their favor, and may be made to flow permanently.

It will be remembered that during the extra session of 1839, a law was passed and the sum of $30,000 appropriated for the purpose of making surveys for a continuous railroad from Harrisburg to Pittsburg, and Charles L. Schlatter, Esq., was appointed to conduct these surveys. A further sum of $15,000 was granted by the next legislature, and the report of the engineer is now being published.

Being fully awake to the important influence which the improvement system of our Commonwealth has exercised upon our commerce and industry in its present infant state, and will continue to exercise still more when properly developed, we have watched these movements with an intense anxiety.

We were aware of the popular opinion which then prevailed to a great extent, and was even countenanced by some engineers of standing, that no continuous route for a railroad could be established within the borders of our State, of a reasonable length, without resorting to inclined planes and other objectionable expedients. We entertained these apprehensions ourselves, to some extent, and were therefore most anxious for the result of these extensive surveys, which it appears have been carried on in a systematical manner ever since 1839.

So much greater was our surprise when we learned by the late report of the Canal Commissioners, that not only a route for a continuous railroad from Harrisburg to Pittsburg, had been found entirely practicable without any inclined planes, but that the distance and grades are far less than the most sanguine could have anticipated. We say now, that we have just cause to congratulate ourselves upon a discovery, which, if it be pursued at an early period, will in its train of consequences bestow benefits upon our community of the most durable kind.

But we imagine we hear many exclaim, "How visionary, how impracticable at the present time!—another internal improvement bubble—and such a gigantic undertaking!—two hundred and forty-two miles of railroad, which, when estimated at the actual average cost of our well constructed eastern railroads, will require about eight millions of dollars to complete and put in running order! The State already in debt too deeply, and here comes up another mad scheme, calculated to plunge us eight millions deeper!"

We hear all these objections, and have duly considered them before we formed our conclusions. But we entreat you to reflect calmly before you decide—and at the same time, we appeal to your *patriotism as Pennsylvanians.*

The matter which we present to your consideration, fellow citizens,

cannot be urged in terms too strong or too expressive. A longer disregard, we apprehend, threatens to injure the future prosperity of a large portion of our State, and of our commercial metropolis in particular. We solicit your full attention, not to phraseology and exclamations, but to matters of fact, with which alone we pretend to deal in thus appealing to you.

Can we look on calmly any longer and see how Baltimore is striving to bring her harbor within twenty hours reach of Pittsburg, by the Baltimore and Ohio Railroad? The whole line of this important work is now constructed or under contract as far as Cumberland. A few years more, and that enterprising company will have finished a continuous line to Pittsburg and a branch to Wheeling. Philadelphia will then see, that the whole of her winter trade and the greater part of her spring and fall goods, and three-fourths of all the travellers will take their way from Pittsburg to Baltimore, and vice versa, instead of following the old accustomed channel to Philadelphia.

The completion of the Tide Water Canal, has already turned a large portion of our internal commerce in favor of Baltimore. This was the natural consequence of an artificial cause, and we cannot prevent it, since that cause is established on a correct principle. But since we have it in our power to call forth other agencies, which will work wonders in our favor, it is but our own folly, if we allow our rivals to crush our interests by their greater sagacity and foresight.

It is not the mere effect of the propensity of acquiring filthy lucre, which makes nations rival each other in commerce and industry. The philanthropist and philosopher takes a higher stand, in viewing the active strife thus carried on honorably between different sections of a common country, and between distant nations and climes. It is the activity of commerce and industry, and the constant intercourse in consequence of it, by which the dormant faculties of mankind are called forth to act, and contribute largely to advance the cause of humanity, and develope the infinite resources of rational enjoyment and gratification.

It will not do for Pensylvania to stay behind the age of enterprise, and to wait till it is too late to commence. We all know how difficult it is to divert a trade from an old accustomed channel, where it has been fostered for years. And we also know, with certainty, that the population and consequent business will not decrease, but increase in a certain, though moderate ratio. Our communications should, therefore, be planned with a view to the future, and the revenues to be expected may be justly anticipated to increase in proportion to the rising population.

NORRIS'S LOCOMOTIVE ESTABLISHMENT.

We have the pleasure, this morning, through the kindness of Mr. Norris, of presenting our readers with an account of his extensive establishment for the manufacture of Locomotive Engines.

The factory of Mr. Norris is situated on Bush Hill, a little north of the Columbia Railroad. The ground occupied by the buildings is computed, in the aggregate, to be at least an acre and a half. The buildings are separated by Schuylkill Sixth street, which runs through them. On the east side of the street is the main building, with the blacksmith shop brass casting, and file cutting establishment; and on the west side is the carpenter's shop, pattern maker's shop and boiler house, to the latter of which is attached a blacksmith shop. The buildings are rather irregularly situated, but the establishment combines within itself every facility for the performance of work.

The main building is about one hundred and fifty feet long, by forty

wide. On the first floor, a track is laid down on the south side, and here the engines are put together. Along the northern side, benches for the workmen are ranged. At the western end of the room, are lathes of every description, all of them driven by steam, and so arranged by machinery, that they require but little attendance after being once set. Some of them are of very ingenious construction; and we regret that our limited space will not permit a particular description of them. In this room were some truck frames. They are composed entirely of heavy wrought iron, and are specimens of great skill and neatness in forging. The machinery in this building is driven by a steam engine, which is placed in the cellar. The steam power is carried a considerable distance across the street, and into the boiler house, where it is used to drive a boring mill and punching machines.

In the second story, a busy and enlivening scene was presented—the room being filled with workmen engaged in preparing the various parts of the engine. The workmen's benches are arranged round the sides of the room, and down the middle. A large quantity of work was in a state of forwardness, while the number and variety of tools in use was immense. This is called the finishing room.

In the third story, the lighter parts of the work are performed. In both the last named rooms, we saw some beautiful specimens of work, both in iron and brass. To the south of this building, is the foundry for brass castings, and the file cutter's shop. In the yard is a powerful engine, worked by steam, and having attached to it a large reel of hose, so that, in case of the occurrence of a fire, it can be promptly extinguished. Running in a parallel line with the main building, is the shop where the engines, after being put together, are tried, so as to insure their being perfect, before sent away. Near this is the blacksmith shop, said to be one of the best in America. The number of forges in constant operation is twenty-seven; and at one of them, the frame of a locomotive was being forged. It is one of the improvements of Mr. Norris, that the frames of his engines are made of heavy wrought iron, in one piece. The forging of them is very difficult indeed. There will, in a short time, be erected here a trip hammer capable of faggoting a bar of iron six inches in diameter. The blacksmith shop has a front both on Sixth and Fairview street, and is admirably constructed for the admissin of light and air, as also for the immediate escape of smoke. In a room to the north of this are very heavy lathes, for the turning of wheel tires; and also a horizontal lathe, for boring the centres of wheels, as also the eccentrics for driving wheels. Mr. Norris is about putting up a stationary engine, for the purpose of driving the whole of the machinery of the establishment by steam, as also by means of the fan, to furnish blast for the forges.

On the west side of the street, on the first floor, is the carpenter shop, where all the wood work necessary for an engine is made, as also the heavy frames for the tenders. In the second story is the pattern shop, and here we saw a diminutive locomotive engine, complete in every particular, and capable of drawing five tons on a level road. It is intended for the Royal Conservatory at Berlin. It is, even to the smallest part, an exact copy of the larger class. From this room we passed into the boiler shop. This room is of large dimensions, and is filled with boilers in various stages of forwardness. One of them, intended for an engine which is to go to Berlin, was made of copper. Around the room, forges are placed at convenient distances, for the purpose of heating the boiler rivets, or any other part of the boiler which may be necessary. Attached to this is a blacksmith's shop, but the work done in it is exclusivesly for the boiler shop.

The work done at this establishment has a great and justly acquired reputation. Not only in our own country, but throughout Europe, the name of Mr. Norris has been made known, and his engines tried. From the period of the establishment of this factory, Mr. Norris has made and sent off one hundred and forty-two engines; and of these there have gone—

To Germany,	2.
To Austria,	5, and 2 yet to go.
To Prussia,	7, and 10 yet to go.
To England,	16.
To Cuba,	7, and 6 yet to go.
To Canada,	1.

The number of workmen now employed is three hundred; but there is ample room for four hundred and fifty. It is calculated that, independent of the boiler, they can complete an engine in seventeen working days; and in the ordinary course of work, can perform *all* the work required on an engine in the space of one month.

The veiw of this factory has afforded us unmingled pleasure. Extensive as it is, it shows us but an example of what individual enterprise can accomplish. Establishments of this kind are a credit, not only to the city in which they are located, but also to the State, and should be supported by all who have at heart its honor and well-being.

PROGRESS OF CIVIL ENGINEERING.

Account of Dircks' Patent Improned Metallic Railway Wheels with Wood-faced Tyre, read by MR. HENRY DIRCKS, *before the Mechanical Section of the British Association, at Glasgow, Sept.* 19, 1840. *And also before the Polytechnic Society, at Liverpool, Oct.* 8, 1840.

As an introduction to the observations immediately relating to the improved wheel which is the subject of the present communication, a few preliminary observations may serve to make its nature and advantages more generally understood.

Wooden wheels were originally in common use on railways; these were afterwards superseded by the extensive use of cast iron wheels; and both of these descriptions of wheels were much improved by manufacturing them with wrought iron tyres. Modifications of these wheels are still in use on the Liverpool and Manchester Railway, the wooden wheels having the nave of cast iron, and the spokes and rim of wood, the tyre being of wrought iron. On the London and Birmingham Railway, cast iron wheels are extensively used. On the Continent of Europe, and in America, cast iron wheels are seemingly employed by preference; and are no doubt quite as safe for travelling, where great speed is not practised.

In England, a decided prefereuce is given to wrought iron wheels, in which this metal is used throughout, with the exception of the boss being *cast* around the ends of the spokes. The latest improvement on these has been the making of the entire wheel, including the boss, of wrought iron.

The wheels now in general use derive their chief novelty from the construction and placement of the spokes, with a view to obtain elasticity, strength, and durability. One variety which does not

come under this denomination, is the plate wheel, supposed on its introduction to possess some peculiar advantage in overcoming a supposed resistance of the atmosphere. Except, however, in relation to variations in size, the present wheels are little more than varieties in pattern. The common diameter of carriage and wagon wheels is three feet, and the largest driving wheels for locomotives are those employed on the Great Western Railway, being six or seven feet in diameter, though at one time they were made as large as ten feet.

The action of an iron wheel on an iron rail, though derived from a rolling motion, can only be compared to a series of blows, and the rebound occasioned by iron striking iron is well known to be considerably greater than is produced by striking wood on iron. To this simple fact we may trace the tremulous motion occasioned by iron wheels on an iron railroad; and when, by any trifling accident, as an inequality from the rising of one end of a rail, or sometimes even from small flinty pebbles getting on the rail, the rebound is not more fearful than dangerous. The tremulous motion of the rail just adverted to renders it necessary in most cases to lay the rails on wooden sleepers. As an illustration of what is meant, it may be mentioned that on the Dublin and Kingstown Railway the rails were originally laid on granite sleepers, but the tremor was so great as to loosen the rails, and occasion serious fears from the consequent damage sustained by engines and carriages passing along the line. It was, therefore, ultimately agreed to take up the granite and lay down longitudinal wooden sleepers, a work of considerable labor and expense. In some cases the nature of the soil or sub-soil may allow the use of stone blocks; and where they can be applied with safety, they are preferred, for the reason that a road laid on *stone* blocks can be kept up at a lower rate than one laid on *wooden* sleepers; and, as has been endeavored to be clearly shown, the only reason for laying the stone aside, arises from the tremor imparted to the rail by iron wheels as at present used.

We shall now proceed to a description of the improved metallic wheel with wood-faced tyre, showing its advantages in connection with the preceding observations. The construction of the wheel may be understood by imagining a spoked wheel with a deep channelled tyre. The wheel may be made either of cast or wrought iron, it having been ascertained that tyre bars can be rolled to the required pattern. In this channelled tyre are inserted blocks of African oak, measuring about four inches by three and a half inches, solidified by filling the pores with unctuous preparations; thereby counteracting the effects of wet by capillary attraction,—to which, by this means, it becomes impervious, and at the same time is not liable to unequal contraction and expansion. The blocks of wood are cut to the requisite form to fit very exactly in the external circular channel of the wheel, with the grain placed vertically throughout, forming a complete facing of wood. There are about from twenty-eight to thirty of these blocks round each wheel, where they are retained in their place by one or two bolts passing through each, the two sides of the channel having corresponding holes

drilled through them for this purpose; the bolts are then well rivetted. After being so fitted, the wheel is turned in the usual manner. The wheel, when finished, has all the appearance of a common railway wheel, but with a rather deeper rim, the tyre faced with wood, and the flange of iron. Woods of various qualities may be used, whether hard or soft, requiring different chemical preparations according to their porosity, and in some instances requiring to be compressed.

The several advantages which this wheel possesses, are—

1. That the wood facing will wear a considerable time without requiring any repair.

2. That the wood can be refaced, by turning it up again in the lathe, as practised with worn iron tyres.

3. That the tyre can be refaced with wood at little expense, and at a far less loss of time than usual. In the operations of re-facing these wheels, or putting in new wood, the work can be performed without the labor and cost of renewing the wheels from the axles, which in the keying and unkeying is known to be very troublesome.*

4. That in regard to their working, it is the opinion of practical engineers, confirmed by actnal experiment, that they will work smoother, easier, and, as some have expressed it, more "sweetly" than iron-tyred wheels; with the advantage of going well in wet weather, even upon inclines,—having sufficient adhesion to the rail, without dropping sand to assist them in this respect, as practised when iron wheels are used.

5. That another and very important result will be, that the rails themselves will suffer less wear by using this kind of wheel, and that the fastenings, sleepers, and blocks will receive considerably less injury, and thereby favor the laying of railroads on stone blocks, wherever they are considered to be most desirable.†

A metalic wheel with a wood-faced tyre, which is the principle of this construction, obviates most, if not all, the difficulties which have been experienced, whether in the use of wooden, cast iron, or even wrought iron wheels. Cast iron wheels may, indeed, now be considered not far short of being equal to wrought iron wheels, for safety and durability, with all the superiority of which the application is susceptible. They are also neither clumsy nor inelegant in form, and are capable of being made to any pattern, even for carriage wheels for common roads. It may, therefore, very possibly occur that they will have the effect to bring cast iron wheels into as general use and as much reputation here as on the continent. This new construction and simple adoption of wood makes excellent driving wheels for locomotives; it may be readily stopped, by using a cast iron brake, and does not undergo that wear, which might be expected from the friction it then has on the

* As in every thing affecting railways, it is a desideratum to decrease the expenses as much as possible, it may here be mentioned that three feet cast iron wheels, with wood-faced tyres and wrought iron axles complete, can be made much cheaper than the generality of wheels.

† On lines situated like the Greenwich Railway and the Blackwall Railway, wood-faced wheels would diminish much of the noise which at present is a source of general complaint.

rail. The wood, by use, becomes exceedingly close and firm, acquiring a surface not easily distinguishable from metal in appearance.—*Civ. Eng. & Arch. Jour.*

Specification of a Patent for a new Combination of Ingredients to be used as a Substitute for Oil, for Burning in Lamps; granted to ISAIAH JENNINGS, *city of New-York, December* 31*st*, 1839.

To all whom it may concern, be it known, that I, Isaiah Jennings, of the city of New York, have invented or discovered a new combination of ingredients to be used as a substitute for oil and other combustible ingredients, for burning in the various kinds of lamps now in use; and I do hereby declare that the following is a full and exact description thereof.

In the process of distilling whiskey for making alcohol, or high wines, it is now the practice with some distillers to commence the operation by subjecting the whiskey in the still to a much more intense degree of heat than heretofore, and as the progress of rectification proceeds to lower the fire to the ordinary temperature. The effect of this high temperature is, in the first instance, to drive over a liquor possessed of peculiar properties, intimately related to those of the essential oils. The quantity of this liquor obtained from different parcels of whiskey will differ, but I think that it will vary but little from two or three gallons to the hundred gallons of common whiskey. Its specific gravity is the same, as nearly as may be, with that of spirits of turpentine, and its reaction is, in many cases, similar. It is extremely high flavored, and brings over with it all the highly odorous matter contained in the whiskey, and has, consequently, an offensive smell. The reason for adopting this process by the distiller, is, that by driving over this oil, or spirit, which I shall designate by the name of *oil of whiskey*, the trouble and loss consequent upon rectification by charcoal, are avoided, and an equally pure spirit is obtained.

I have been thus particular in the foregoing description, as this peculiar kind of oil or spirit possessess the property of rendering alcohol and spirits of turpentine capable of combining with each other in proportions in which they do not combine when it is not present; and will also cause spirits of turpentine to combine with whiskey, or ordinary proof spirit.

In making my new compound, the spirits of turpentine may be the predominating ingredient, which cannot be the case when the compound of this spirit with alcohol is used alone. The proportions may, of course, admit of some variation, but the following is preferred. Two parts of spirits of turpentine; one of alcohol of 93° above proof, and one of oil of whiskey. Should alcohol of higher proof be used, the proportion of spirits of turpentine may be increased, but this is not deemed desirable. Tne advantage derived from this oil of whiskey is such, that were it not added, as above, the alcohol must exceed the turpentine in the proportion of about five to one.

I sometimes combine the oil of whiskey with sperm, or other oil, with turpentine, and with alcohol, or with the sperm oil alone;

which last combination will take place in any proportions. When I use the four ingredients I prefer to take about four parts of the oil of whiskey, one of sperm or other oil, one spirits of turpentine, and one of alcohol.

The fluid which I have denominated oil of whiskey, has, heretofore, been thrown away as worthless, but I have, as aboved stated, applied it to a highly useful purpose, and obtained a combustible fluid affording a brilliant light, at a cost far below that of the ingredients now in use, and which, when combined, as above stated, has not its offensive smell developed, but burns without odour.

What I claim as my invention or discovery, in the above named combination of ingredients, is the use and employment of what I have denominated oil of whiskey with spirits of turpentine, alcohol, or lamp oil, in the manner, and for the purpose, herein set forth.

ISAIAH JENNINGS.

In July, 1839, an article was brought to us for examination under the name of "Oil of Rum," which appears to be the same substance, so ingeniously applied by Mr. Jennings. A few experiments satisfied us that it was not, as had been supposed, impure spirits, but rather an oil containing a small quantity of alcohol, and perhaps water. It is also exceedingly pungent; sufficiently so to scent a large apartment when a vial containing a few ounces was opened for a short time. The taste was quite as fiery as that of alcohol. By some accident it was tried in a spirit lamp, and found to give a great heat, and in the proper management produced no smoke. It appears that the present mode of distillation has led to the discovery of a separation of this oil, and it is not improbable that its uses may be greatly extended, while its absence from the spirits will greatly improve the quality of the latter.

The following article on the same substance contains much interesting information.—[Ed.]

On the Potatoe Spirit Oil of the French Chemists. By JAMES APJOHN, *M. D., M. R. I. A., Professor of Chemistry in the Royal College of Surgeons, Dublin.**

In December, 1838, I received from my friend Mr. Scanlan a specimen of an oily fluid which had been given him by Mr. Bowerbank, an eminent London rectifier, and which the latter gentleman had found in small quantity in the faints or weak spirit drawn off towards the close of the rectification of common whiskey. Shortly previous to this time, Mr. Coffey, the inventor of the celebrated patent still, had observed the same substance at the extensive distillery of Sir Felix Booth; and upon coming over to Dublin, and visiting the establishment of Mr. Busby at Blockpitts in this city, Mr. Scanlan had the satisfaction of recognizing this same oil in the faint vessel, constituting a thin stratum resting upon the surface of the remainder of the fluid.

* Communicated by the Author.

The oil obtained from Mr. Busby's concern had a reddish-brown color, owing to dissolved vegetable matter, and its specific gravity was ·8401, that of the faints on which it rested being ·9269. Shaken in a graduated tube with an equal bulk of water, its volume was reduced 20 per cent., and the water upon distillation yielded alcohol. To insulate the oil, therefore, the following method was adopted.

The fluid obtained from the faint receiver was first washed with an equal bulk of water; then shaken in a bottle with an equal weight of pulverized and anhydrous carbonate of potash, and finally distilled from a glass retort, the condensation being effected by Liebig's tube refrigeratory. It began to boil at 262°, after which the temperature rose gradually until it became 268°, at which it continued until the whole of the oil was nearly over. The fluid first drawn off was set apart, as still containing alcohol, and that alone reserved for further purification which distilled over at 268°. This portion was redistilled. The ebullition commenced a little over 267°, and in less than a minute rose to 268°, at which point it continued until the rectification was nearly completed. The first and last portions being rejected, the middle portion, or that which came over 268°, was set apart for experiment.

The oil thus procured is a perfectly colorless liquid, destitute of all viscidity. The specific gravity is ·8138, and, as has been already observed, it boils steadily at 268°; cooled to —6°, it does not congeal. With rectified spirit it is miscible in all proportions, its specific gravity being thus augmented, and its boiling point lowered. It is immiscible with water, but nevertheless, when agitated with this liquid, it absorbs an appreciable quantity of it. It has a pungent and peculiar odor, and a sharp, biting taste, somewhat similar to that of the oil of cloves. When gently heated it readily takes fire upon approaching to it a lighted taper, and burns with a clear flame, unaccompanied by smoke. It is an excellent solvent for the fats, and also for resinous substances. Camphor, for example, is readily dissolved by it; and the same may be said even of copal, if a gentle heat be applied. Potash is taken up by it in considerable quantity, oil of vitriol gives it a crimson color. To determine its composition the following experiments were made:

(1.) 4·24 grains of oil burned in the usual manner with oxide of copper gave of water 5·06 grains, and of carbonic acid 10·42 grains.

(2.) 7·71 grains gave of water 9·22 grains, and of carbonic acid 19·12 grains.

(3.) 6·63 grains gave of water 8·05 grains, and of carbonic acid 16·26 grains.

The following are the results deducible from these experiments:

	(1.)	(2.)	(3.)
Carbon	67·96	68·59	67·84
Hydrogen	13·25	13·28	13·48
Oxygen	18·79	18·13	18·68
	100	100	100

The means of the numbers yielded by the three experiments are

given underneath in column (*a*). The numbers in column (*b.*) are the quotients of the corresponding ones in (*a.*) divided by the respective atomic weights of carbon, hydrogen, and oxygen, and those in column (*c.*) are others in the same ratio with the quotients.

	(*a.*)	(*b.*)	(*c.*)
Carbon	68·13	11·132	4·804
Hydrogen	13·33	13·330	5·753
Oxygen	18·54	2·317	1·00
	100·		

The inspection of the latter shows that the most probable formula for the oil is $C_5\ H_6\ O_1$, which would give the following parts per cent.

Carbon	68·60
Hydrogen	13·45
Oxygen	17·95
	100·

Assuming this formula as the true one, the deficiency in the carbon experimentally determined is not greater than what usually takes place; but the error in the hydrogen, though trifling in amount, being upon the opposite side to that on which it usually occurs, it became expedient to resort to some method of verification. The specific gravity of the vapor of the oil was therefore taken according to the well-known method of Dumas.

The weight of glass ball filled with dry air, the pressure being 30·324 and temperature 48°·5, was 914·86 grs.

The ball was sealed at 364°, and then weighed 917·78 grains. Hence 917·78—914·86=2·92 grains is the excess of the weight of vapor in ball over that of the air displaced.

The capillary end of the beak attached to the ball having been broken under mercury, it was ascertained by the amount of this metal which flowed into the ball, that its capacity was 16·76 cubic inches, which, at a pressure = 30, and a temperature = 60°, will (supposing it air) become

$$16{\cdot}76\times\frac{448+60}{448+48{\cdot}5}\times\frac{30{\cdot}324}{30}=1{\cdot}7333$$

cubic inches. From this must be subtracted ·1 cubic inch which was found to remain in the balloon, so that the bulk of air excluded by the vapor, when reduced to the mean temperature and pressure, was 17.233 cubic inches, whose weight = 5·344 grains. Hence 2·92+5.344 = 10·264 is in grains the weight of the vapor.

The capacity of the glass balloon at 48°·5 being 16·76 cubic inches, it will, owing to the expansion of glass, become at 364° 16·843 inches. This, therefore, is the volume of the vapor and bubble of air at 364°. But the volume of the latter being 0·1, it will at 364° become 0·16. Hence the true volume of the vapor at 364° = 16·843 — 0·16 = 16·683; so that

$$16{\cdot}683\times\frac{448+60}{448+364}\times\frac{30{\cdot}324}{30}=10{\cdot}549$$

is the volume of the vapor reduced to a temperature = 60°

and pressure = 30. But as this weighs 10·264 grains, 100 cubic inches of it would weigh 97·298 grains. The specific gravity, therefore, of the vapor is $\frac{97·298}{31·0117} = 3·137$.

Now if the composition of the oil be C_5 H_6 O_1, the specific gravity got by adding together the products of the densities of the vapors of the different elements by the number of atoms of each would be 3·072. But we have here so close a correspondence between experiment and calculation, that no doubt can remain as to the correctness of the basis on which the latter rests, or that the true formula for the oil is that already assigned.

These experiments were made in the winter of 1839, and at the time I had concluded them I was under the impression that the oil, to which they relate, was a new substance, or rather one which had not been previously described. In some time after, however, upon looking over the second part of Mr. Graham's Elements of Chemistry, which had been sent me by the author, I was much surprised at finding at page 134, in a table of the volumes of atoms in the gaseous state, mention made of a substance under the designation of "oil of the ardent spirit from potatoes," to which he attributed the very same formula and density of vapor which I had found to belong to the oil found in grain-whiskey, in the examination of which I had been recently engaged.

Anxious to investigate the matter further, and to ascertain if the two oils were certainly the same, I looked into Berzelius's System, and the 5th volume of the *Traite de Chimie, appliquee aux Arts*, by Dumas, devoted to the subject of organic chemistry, but could not find any mention in either of the essential oil from potatoe spirit alluded to by Graham. Upon, however, turning to Dr. Thomson's recent volume on vegetable chemistry, I found, page 481, a notice of this fluid, and references to the 30th and 56th volumes of the *Annales de Chim. et de Phys.*, in the former of which its origin and properties are described by Pelletier, and in the latter of which its analysis is detailed by M. Dumas. The properties I find ascribed by these chemists to the potatoe spirit of oil are precisely those which belong to that which I have examined from corn-whiskey, the only difference being that Pelletier represents its specific gravity as ·821, whereas I have found that of the oil I obtained from Mr. Scanlan but ·813, a difference, however, easily explained by the circumstance of his not having taken the necessary steps for rendering the fluid he examined perfectly free from water and alcohol. The analytic results also of M. Dumas are nearly identical with mine, approaching, however, more nearly, as might indeed be expected from his great skill in this department of chemistry, to the formula C_5 H_6 O_1 which he adopts, and which Professor Graham has taken from his memoir. I may lastly mention, as a very unusual coincidence, that the specific gravity of its vapor, as obtained by Dumas, is 3·147, or but unity in the second place of decimals greater than what has resulted for the corn-spirit oil from my experiments.

We thus arrive at the conclusion, that the two fluids are identical, or that the oil which has hitherto been considered as peculiar to potatoe spirit, occurs also in that which is developed during the fermentation of grain. From this latter source it admits of being procured in great quantity. When first observed by Mr. Coffey at Sir Felix Booth's, there was an inch of it in the faint receiver, and from the diameter of the vessel he estimated its total amount at 50 gallons. This is the quantity produced at that establishment every fortnight, the excise laws compelling the distiller to distil and brew alternately, and a week being generally consumed in each process.

The whiskey manufactured some years ago contained a considerable quantity of this oil, and owed to its presence a great deal of the pungency of taste by which it was distinguished.

From its high boiling point, and the nature of the stills at present used, but a very small portion of this substance now passes over, and hence the reason why the spirit at present made is, as compared with the product of the old processes, less disagreeable to the palate, and probably less injurious to the constitution. It is no doubt owing to the same cause, viz., an improvement in the process of distillation, that this oil has at length been noticed in the distillers' faints. Upon the old system of manufacture the greater portion of it was driven over, and was held dissolved by the spirit into which it was thus introduced; but with the modern stills, particularly that devised by Mr. Coffey, nothing having so high a boiling point as this oil can by possibility pass into the part of the apparatus where the spirit is condensed. With respect to the manner in which the substance originates, whether it exists ready-formed in the materials subjected to fermentation, or is a product of the process, I am not aware of any facts calculated to decide such a question. As, however, it is found in the fermented wash of both corn and potatoes, it may be presumed to be derived from the starchy principle which is common to both.

The potatoe spirit oil, as it has hitherto been called, has I find of late attracted much attention. Pelletier, from some rough experiments upon it with acids, threw out the conjecture that it was more analogous to alcohol than to the true volatile oils, and this opinion would seem to have been in some degree adopted by Dumas. More recently (*Ann. de Chimie et de Phys.*, Jan., 1839) M. Auguste Cahours has revived this opinion, and concluded it to be one of the group including alcohol, pyroxylic spirit, and acetone, and has even succeeded in procuring from it a carbo-hydrogen, in which the elements are, as usual, associated in the ratio of atom and atom. M. Cahours represents potatoe oil by the formula $C_{10}\ H_{11}\ O_1 + HO$, which makes it as to composition perfectly analogous to ordinary alcohol. The carbo-hydrogen $C_{10}\ H_{10}$ he insulated by distilling the oil from anhydrous phosphoric acid. He calls it amylene, and finds the specific gravity of its vapor to be 4·904, so that an atom of it gives but one volume of vapor; a circumstance in which, as Cahours observes, it agrees with Dr. Kane's mesitylene, $C_6\ H_3$, but differs from the carbohydrogens which occur in alcohol and pyroxylic spirit. By acting on potatoe oil with sulphuric acid and chlo-

rine, Cahours obtained compounds corresponding perfectly with those yielded by alcohol when similarly treated. These researches give additional interest to the discovery of this fluid in grain-fermented wash, and in such quantity as to be much more than adequate to meet any demand for it with a view to the interests of science.

I may here observe, that I should have long since presented this notice to the Academy, but for the following reasons.

There is another oily substance having, at common temperatures, the consistence of butter, which is long known to exist in the faints of grain spirit, and in smaller quantity in the spirit itself. Upon looking through systematic treatises on chemistry, I found that this oil had been very imperfectly described, and that, in particular, no experiments had been made with the view of determining its composition. I had therefore resolved to submit it to an accurate examination and analysis, and to keep back what I had ascertained in reference to the fluid oil until I had completed my invostigations into the nature and constitution of that which is a soft solid at common temperatures. In this investigation I had made some progress, when my attention was directed to a paper by Liebig and Pelouze, in the 63rd volume of the *Ann. de Chim. et de Phys.*, in which, with their usual ability, they develope the nature of a butyraceous or fatty product which they had received from M. Deleschamps, and which comes over towards the close of the process of distilling wines with a view to the production of *eau de vie* or brandy. This oil they found to be a mixture of an acid which they called œnanthic acid, and of a compound of this acid with the oxide of æthyle, that is, of œnanthic acid and œnanthic æther. Upon perusing this paper I saw at once, from the experiments I had already made, that the fatty oil of grain and spirit was identical with this mixture, with the exception that some third oleaginous material was present, which Liebig and Pelouze had not found in what they had operated upon. Upon this third substance I have made some experiments, the results of which I shall probably at some future period submit to the Academy. I have resolved, however, no longer to defer giving publicity to my experiments identifying the fluid oils of grain and potatoe spirit, having had my attention drawn by Dr. Kane to a recent volume of Poggendorff's *Annalen*, containing a paper by M. Mulder, in which I find myself anticipated on the other point; and the butter of corn spirit is satisfactorily shown to be what I had concluded it to be, not entirely from my own experiments, but from a comparison of them with the researches of Pelouze and Liebig. Mulder also notices the third principle which is associated with the œnanthic acid and œnanthic æther, and describes it under the name of *oleum siticum*. The object, therefore, of the present communication is much more limited than it was originally intended to be, professing only to announce the detection of the potatoe-spirit oil of Pelletier and Dumas in fermented infusions of the mixed grains employed by the distiller. But as Mulder conceived his discovery of sufficient interest to justify him in giving it to the scientfiic world, I shall, I trust, be pardoned for bringing an analogous fact under the notice of the Academy.

The importance of the Ohio and Chesapeake Canal, as one of the great works of the Union, has induced us to devote more than usual space to the Report of Mr. Morris.

That portion which relates to the tunnel will be found highly interesting, as descriptive of one of the largest works of this character in the United States.

REPORT OF ELLWOOD MORRIS, CHIEF ENGINEER OF THE CHESAPEAKE AND OHIO CANAL.

CHESAPEAKE AND OHIO CANAL LINE,
December 31st, 1840.

To the President and Directors of the Chesapeake and Ohio Canal.

GENTLEMEN:—Pursuant to your order of December 15th, 1840, directing me to report,—1st. Generally upon the state of the work above dam No. 6.--2nd. Upon its probable aggregate cost, and the amount of work now done and to be done, &c. &c.

I have the honor to submit the following report, which, though somewhat more general, will be found to comprise the 1st head of your instructions.

And with a view to perspicuity, I propose to treat the subjects considered in three divisions:

1.—Entering succinctly into the history and design of the work, viewing it as a route connecting the Western waters with the sea.

2.—Treating of the canal now under construction from Cumberland, 50 miles down stream to dam No. 6.

3.—Noticing briefly the condition and prospects of the finished Canal, now navigated up stream from Georgetown to dam No. 6, a distance of 134 miles.

Work done during all 1840, *upon the* 50 *miles of unfinished Canal below Cumberland.*

WORK DONE.	From Jan. 1st, to May 1st, 1840.	From May 1st, to Dec. 31st, 1840.	In all 1840.
Upon the Sections, ...	$137,060 29	$304,166 67	$441,226 96
Upon the Masonry, ...	22,288 13	67,645 54	89,933 67
Upon all the species of work,	159,348 42	371,812 21	531,160 63

By this statement, derived from the actual estimates made to contractors up to January 1st, 1841, it appears that work to the amount of $531,160 has been actually done in all 1840.

From information contained in the 12th annual report, we find that,

On the 1st of May, 1840, work done on the 50 miles of unfinished canal, amounted to	$2,242,945
To this add, work done from May 1st, 1840, up to January 1st, 1841,	371,812
And we have, total work actually done upon the 50 miles up to January 1st, 1841,	2,614,756

My predecessor, both in his revised estimate of December, 1838, and in that again revised of December, 1839, states the probable aggregate cost of the 50 miles of canal alluded to at $4,440,657

From which deduct work done January 1st, 1841, 2,614,757
And by that estimate, there will now be required to complete the canal an expenditure of 1,825,900

But my personal knowledge of the exact state of the unfinished line, together with the progress already made in the estimate I shall hereafter present, justifies me in the confident expectation that, by dispensing with some works not absolutely necessary—by building the remaining locks of rubble stone masonry (a mode not equal to that now adopted, but better suited to your financial condition)—by modifying the construction of some other works, and—by the probable reduced rates at which, with present prospects, the remaining work could now be let, an economical and judicious outlay upon the works, of a sum *not exceeding* $1,600,000 more, would enable you within 2 or 2½ years, to open the navigation of the canal from the Cumberland dam, throughout the 50 miles now unfinished, and thereby to complete the long anticipated continuous navigation from the county seat of Allegany, to tide-water within the District of Columbia.

1.—*On the General Design of the Chesapeake and Ohio Canal.*

The topography of the continent of North America, southward of the great chain of lakes, is remarkably simple in its general features; it consists of one magnificent valley—that of the Mississippi—of two mountain ranges—the Rocky Mountains, and the Alleganies—and of two sea slopes—the eastern draining into the Atlantic, and the western into the Pacific Ocean.

About three centuries ago, civilization first set foot upon the Atlantic Slope, and extending her domain gradually along the seaboard, it is scarcely a single century since the first settlements were planted beyond the Alleganies, in the eastern margin of the great valley referred to.

But within this short period, our enterprising countrymen have extended themselves so rapidly, as now to occupy the whole eastern slope of the Mississippi valley and a portion of the western. The great central valley having been mainly peopled by immigration from the Atlantic slope, and much of the foreign trade in articles of western consumption being still carried on through the Atlantic seaports, which afforded reciprocally a market for the products of western industry; it was very natural that our countrymen, both in the East and West, should early contemplate perfecting the communications between their old and new homes, even by subduing the obstacle, which nature had upreared in those numerous mountain ranges known as the Alleganies. Accordingly, we witness the great States of the seaboard, at immense expense, vieing with each other in establishing magnificent lines of transportation, to secure to themselves, as far as practicable, the traffic of that vast basin from which they are separated by the lofty crests of the Apalachian chain.

Stupendous are the barriers interposed by nature, but dazzling the stake they play for—costly must be the honorable strife, but splendid the reward accruing to that State which shall ultimately possess the most perfect line of western communication.

The trade with the great West naturally divides itself into two distinct branches—one light, demanding expedition, the other heavy, in which time is less an object; with extraordinary facilities for both, nature has singularly favored Maryland.

These advantages were early perceived and appreciated, by those valiant men who led the chivalry of the seaboard, in that ill-starred march, which terminated on the fatal field near Fort Duquesne, where Braddock fell a victim to his inexperience in woodland warfare.

There was one commander in that army whose quick eye was ever ready to note topography for future use—who had antecedently pursued his humble occupation of surveyor upon the margin of the Potomac, having been for some time forted upon the present farm of Mr. George Catlett, about 8 miles below your tunnnel—and whose comprehensive mind quickly grasped the advantage offered by the valley of the Potomac as a western route, owing to that stream severing in succession every one of the numerous rocky ranges, known by the general name of the Allegany Mountains.

This officer—Washington himself—was the early and steadfast patron of improvements upon the line of the Potomac; and soon after the revolutionary peace, in fact on the 22nd of December, 1784, we find General Washington sitting as chairman of a joint commission of Maryland and Virginia, to take into consideration the propriety of improving the navigation of the Potomac to a point high up stream, and thence opening a road to join the western waters.

This commission recommended to the Legislatures of the two States the appropriation of a sum of money towards rendering the Potomac navigable to a point considerably west of Cumberland; thence to form a road cleared 80 feet wide to the Dunker bottom, on the Cheat river, and thence to form a batteau navigation to the Monongahela.

This action clearly indicates that Washington and his compatriots looked upon the improvement of the Potomac merely as forming a link *in a great route west.*

At that early period no one believed it practicable to surmount the Allegany by a continuous navigation; the demonstration of this momentous fact was reserved for those able officers of Engineers, who, under the direction of the U. S. Board of Internal Improvements, made in 1826, the preliminary surveys for the present Chesapeake and Ohio Canal, and who then established, in a most scientific and conclusive manner, that the Allegany summit of this work actually possesses a command of water ample to meet the exigencies of trade.

In 1784 the Potomac Co. was chartered by the commonwealths of Maryland and Virginia, who subsequently commenced operations under that charter, and effected an essential amelioration of the navigation of the river, especially at the Great and Little Falls; but their improvements being found in 40 years to fall far behind the wants of the country, they were superseded in 1824 by the charter of the present Chesapeake and Ohio Canal Company, to whom all the rights, interests, and privileges of the Potomac Company were ceded by a deed of surrender, dated the 16th of May, 1825.

The Chesapeake and Ohio Canal Company was organized in 1825, and on the 4th day of July, 1828, the first ground was broken upon the canal, by his Excellency John Quincy Adams, then Chief Magistrate of the Republic: since that day, with various fortune, this great work has struggled onward, deserted within a few years by all her early patrons, except the commonwealth of Maryland, in whose bosom alone she has of late been fostered.

Although this important enterprise is evidently destined for many years to be nothing more than the Georgetown and Cumberland—or at the most, the Baltimore and Cumberland canal—still as it was originally designed to connect the western waters with the sea, by an artificial navigation, and as the day will come when Maryland will find herself free from debt, and ready perhaps to reap the fruits of her geographical position, it may be as well to notice briefly the physical advantages which nature has lavished on this

state, by laying through her bosom the only western route, possessing a summit sufficiently well watered to guarantee the maintenance of a continuous navigation across the mountains; which by its superior economy in the carriage of the heavy and slow trade, would inevitably enable its proprietor to disregard and overthrow the competition of all the rival lines in such a traffic.

Whoever studies a map of the United States, will perceive these facts—the Erie Canal turns the north eastern flank of the Apalachian chain, by an admirable water route; whils' Tennessee and Georgia with their improvements turning its flank in the south western quarter, have been compelled to resort to railroads; and of all the western lines of transport between these limits, surmounting the crests of the Allegany, none are practicable without a railway portage—save the Maryland route alone; with this line, but two can by any possibility enter into competition, and these are the Pennsylvania and Virginia routes, the relative advantages of which will be perceived by a comparison of the following tabular statements.

VIRGINIA ROUTE,

From tide water on the seaboard to steamboat navigation on the western waters.

TERMINI.	Character of Improvement.	Length in miles.	Height of the Alleganny summit above tide in feet.	Total Ascent and Descent in feet	Miles of Canal.	Miles of Railroad.
Richmond to Covington,	Canal	239	1987	1229	239	
Covington to the Kanawha,	railr'd.	138		2137		138
Tide water at Richmond to steam navigation on Kanawha,	Mixed	377	1987	3366	239	138

The above is deduced from a work upon the "Laws of Trade," by C. Ellet, Jr. Esq., late Chief Engineer of this improvement.

PENNSYLVANIA ROUTE,

From tide water on the seaboard to steamboat navigation on the western waters.

TERMINI.	Character of Improvement.	Length in miles.	Height of the Alleganny summit above tide in feet.	Total Ascent and Descent in feet.	Miles of Canal.	Miles of Railroad.
Philadelphia to Columbia,	Railroad	82		873		82
Columbia to Hollidaysburg,	Canal	172		748	172	
Hollidaysburg to Johnstown,	Railroad	36	2941	2570		36
Johnstown to Pittsburg,	Canal	104		471	104	
Tide water at Philadelphia to steam navigation at Pittsburg,	Mixed	394	2491	4662	276	118

The above information has been deduced from the reports of the Canal Commissioners of Pennsylvania.

MARYLAND ROUTE,

From tide water on the seaboard to steamboat navigation on the western waters.

TERMINI.	Character of Improvement.	Length in miles.	Height of the Allegany summit above tide in feet.	Total Ascent and Descent in feet.	Miles of Canal.	Miles of Railroad.
Baltimore to Georgetown,	Canal	45		294	45	none
Georgetown to Pittsburg,	Canal	341	1903	3158	341	none
Tide water at Baltimore to steam navigation at Pittsburg,	Simple	386	1903	3452	386	none

The above has been deduced from the reports of General Bernard and Dr. Howard.

Although it would appear from the above tables, that the Virginia route possesses a slight advantage over that of Maryland, both in distance and rise and fall, if we consider Baltimore as the terminus, still the great length and ascent of its railroad would utterly prevent a profitable competition in heavy articles—and as to the Pennsylvania route, her 118 miles of railroad, her transhipments, and her small canals of 40 feet surface and 4 feet depth, combined with the great excess of lockage, will forever render it impracticable for that line to compete economically in the transportation of burden, with a continuous canal of 50 feet water line, and 5 feet depth —capable of bearing on its bosom boats freighted with 75 tons weight.

Indeed an able Civil Engineer and distinguished writer has lately urged as the only means by which Pennsylvania can render her works profitable, that she should construct a continuous canal across the mountains, even though it were necessary to pump by steam from the Conemagh the water requisite to feed it!

In commencing the Chesapeake and Ohio Canal upon its eastern section, it was a fatal mistake not to have begun at Cumberland, and proceeded towards the market, instead of from it; had this been done, the work with less than the present outlay would have been now finished to the "Point of Rocks," there connecting upon the one hand with the Baltimore and Ohio Railroad, and dropping into the river by temporary locks upon the other; the minerals of Allegany could have been poured at will either into the city of Baltimore or the District of Columbia; between which last and the "Point of Rocks" a very passable navigation existed formerly by the works of the Potomac company; finished to this point, the canal, without any material prejudice to the mining interest, and with vast benefit to the finances of the state, might have rested until its revenues supplied the means of further progress.

* * * * * * *

This tunnel is 3118 feet long, and its transverse section of excavation 27 feet wide by 25½ feet high, the sides being cut plumb, the top a semicircle, and a solid tow path of rock being left in; when completed, the arch will

necessarily contract its dimensions, and it will then have a water way of 19 feet wide, and 7 feet maximum depth, a solid tow path of 5 feet clear width, guarded by a brick parapet, and the soffit of the arch at the crown will be 17 feet above the water line of the canal—thus offering a convenient and ample navigation for the transit of single boats or boats in a single line.

The excavation hewn throughout its course from the solid rock, has been carried on by means of two sets of working shafts, wrought by horse gins, the shafts being 188 and 122 feet deep respectively; and also by open drift from the south portal, where the excavated materials were carried out upon a railroad laid on the tunnel bottom, and thrown away as spoil bank in the river.

The excavation has been uniformly advanced by blasting in two breasts, first, the *heading*, being a cut of 12½ feet high next to the tunnel; and second, the *bottoming*, being a thorough cut of 13 feet deep, extending from the floor of the *heading* to bottom of canal, or rather to the bottom of the tunnel, which is one foot below.

Upon the 5th day of June, 1840, the *heading*, which by day and night (Sundays excepted) had been wrought, without intermission, since June, 1837, was completed and opened by effecting a junction between the working proceeding north from the southern portal, and that driving south from the deep working shafts: the other shaft workings having been finished in the year 1839.

This junction took place at a point 1503 feet inward from the south portal, and 340 feet deep, beneath the surface of the ground. Upon clearing the way for the instruments of the Engineer, it was found that all the lines and levels previously given in the several workings, under all the disadvantages caused by a transfer of levels down the shafts, by the smoke of powder and by the darkness, verified and coincided with extraordinary precision, whilst the meeting of the workings was exact.

Very little trouble has been experienced in ventilating the workings of this tunnel; no artificial means having ever been either needed or resorted to, except an occasional fire at the feet of the shafts, or in their man holes. The working shafts, having been sunk in pairs, 15 feet clear apart, and joined by suitable man holes, there was never any difficulty in producing a circulation of air by the aid of fire, or in directing the pneumatic current at will, either up or down a particular shaft. And so pure was the air in the *heading*, at 1500 feet from the south or open portal, where no air shaft or artificial ventilation was ever required, that I entertain not the least doubt that a tunnel of the dimensions of this one might be driven in such material, from an open portal, near half a mile under ground, without other ventilation than would be produced by the natural currents of air from the open end. The British miners, in their coal workings, regard 300 yards lineal as the maximum length to be given to drifts without air shafts; but experience here indicates that, in works of this size, penetrating a material which engenders no deleterious gas, 500 yards lineal may be driven with entire safety, and perhaps even far exceeded.

In November, 1839, when the two main workings had approximated within 600 feet of each other, and were respectively 325 and 310 feet deep under ground, the sound of the blasts in both workings was reciprocally heard in each, through the intervening mass of solid rock, resembling a dull tap with a hammer; and when they had attained a distance of 150 feet apart, the sound of the advancing hammers of the miners could be heard through.

The drainage of this tunnel has never been very great, not having, at any time, exceeded an average of *four* cubic feet of water per minute.

As but 1,502 feet lineal of the full section of *bottoming* now remains to

be done, the tunnel excavation is in such a state of progress that, by pressing it vigorously, there would be no difficulty in bringing it alone to completion in 18 months; and inasmuch as the arching could and ought to be commenced before the excavation is all removed, (because the packing behind and over the arch is to be supplied by the spoil of the *bottoming*,) if the manufacture of brick, which has been too long delayed, was promptly commenced, the arch and tow path could be finished, and the tunnel thrown open to the navigation within 30 months.

It was long hoped that arching this work would either be dispensed with entirely, or at the most, that a short arch at the portals would be sufficient; but such is the character of the material, the absence of coherence between the strata, and so extensive the falls of rock from the roof, which are continually taking place, that, having carefully watched this work from its very inception, I have come to the decided conviction that a thorough arch is indispensable to the safe and uninterrupted transit of boats.

As it has been imagined by some that the arching would require a long time, it may be as well to give an outline of the plan upon which I have long contemplated proceeding with this portion of the work, and by the execution of which I have entire confidence that, with a heavy force, this formidable arch, though 3,118 feet long, and requiring about three and a half millions of bricks, can be constructed in a single year: the bricks being prepared beforehand and delivered at the portals.

By the experiment of Col. Pasley, of the Royal Engineers, of Mr. Brunel and others, the cohesive power of cement has been demonstrated to be so great, that from 20 to 30 bricks, with their longest dimension vertical, have been stuck out horizontally from a wall, by adding successively a brick at a time as soon as the cement joint of the preceding one had set.

Acting upon the principle of cohesiveness here developed, possessed, as it is in an eminent degree by the hydraulic cement of the Potomac, which I contemplate using in the arch at least, without any admixture of sand, in order to procure a quicker set and firmer bond, I propose,

1—With a strong force, to raise both side walls up to the springing line of the arch.

2—In sections of, say 5000 feet, by reverse moulds and without centering, to carry up the arch on both sides to the angle of repose, and bringing into play the coherence of the cement, even above it, say to an angle of 40 or even 45 degrees, as may be determined at the time.

3—By a system of detached centres, framed to leave open about 30 degrees of the crown, each supporting three feet lineal of the arch, and leaving an interval of four or more feet to be sustained by the cohesive power of the cement, to carry up the spandrels of the arch to an angle of 75 degrees or within 15 degrees of the crown on each side.

4—By a very light centre, (capable of being handled by two men,) to key up the crown in sections of 2 feet, shifting the centre crown continually, (upon a platform carried by the detached system,) as each successive section of the crown is keyed up and packed.

Those who are conversant with practical affairs, will at once perceive that, by working in long sections, course by course successively, the cement will set in one part whilst the workmen are engaged at another; and that by the division of labor indicated in the above outline, a very large force can be employed upon the arch, and so organized as to finish each part in detail; the most tedious portion, that of keying up, being limited, by the mode of operation, to 30 degrees of the crown alone, or but one-sixth of the semi-circle, can be advanced by working only from a single point, at the rate of 10 feet lineal per day.

(*To be concluded in our next.*)